CHAPTER - 4

GEOMORPHOLOGY

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INTRODUCTION

The landforms are the basic elements in any landscape.It is defined by Howard and Spock (1940) as "any element of the landscape, characterised by a distinctive surface expression, internal structure or both and sufficiently conspicuous to be included in a physiographic description".

In this chapter the present author has restricted his studies to landforms. He attempted to hlight the landscape diversity of this coastal area and has given an account of the various coastal landforms. While describing the landforms he has also attempted to explain their genetic aspects. The total geomorphic picture that has emerged, throws significant light on the various geo-environmental parameters prevailing within the coastal study during the late Quarternary times. Landforms are the products of various processes acting on parent formations and each process leaves its impression on the landscape so that during different geomorphic processes a set of landforms develops

each landforms having different histories. Since the environment shows marked influence on structure and lithology, the environmental factors such as climate, lithology and relief are the important criteria for identifying and classifying landforms attributes of the area.

GEOMORPHIC FEATURES

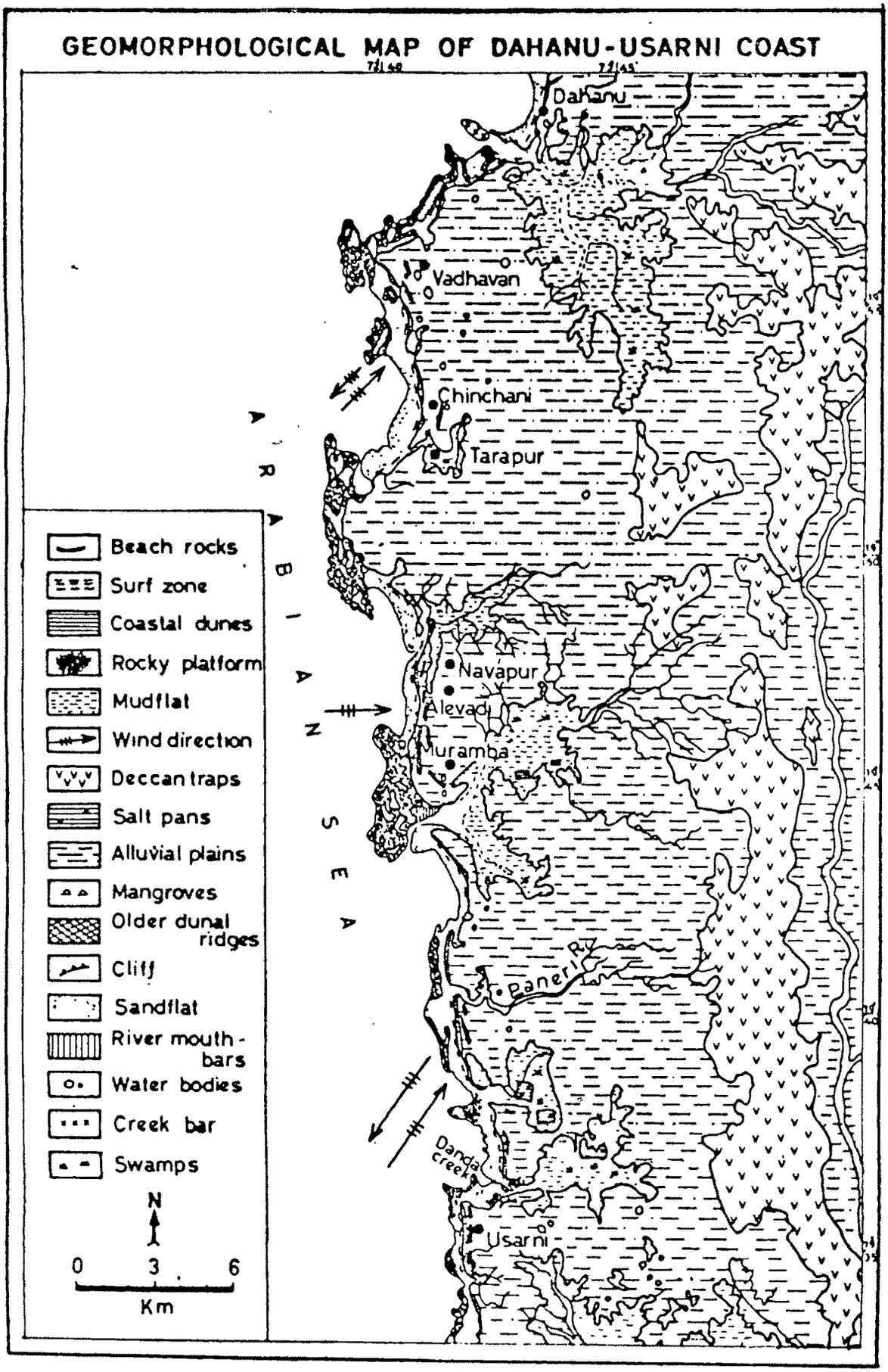
While describing the geomorphic features of the study area, one has to bear in mind the sequence of landform evolution are related to the successive strandline positions. The present day landform assemblage and coastal features - both erosional and depositional in the area, provide a sum total of the geomorphic events of several generations co-existing together (Fig. IV.1).

The cross profile across the coast of the study area seen today, consists of the following features :

(1) Beach (Lower foreshore, Upper foreshore and Berm)
(2) A linear longitudinal plaeoridge
(3) Coastal dunes
(4) Beachrocks
(5) Tidal flats
(6) Alluvial plains and residual soil cover
(7) Hilly basaltic terrain

It is very significant that the above stated features typically reflect the effects of transgression/regression of the sea during the late Pleistocene and early Holocene Epochs. Such

FIG. IV·1


GEOMORPHOLOGICAL MAP OF DAHANU-USARNI COAST
Dahanu
Vadhavan
Chinchani
Tarapur
Navapur
Alevadi
Muramba
Paneri R.
Dandi creek
Usarni
ARABIAN SEA
Beach rocks
Surf zone
Coastal dunes
Rocky platform
Mudflat
Wind direction
Deccan traps
Salt pans
Alluvial plains
Mangroves
Older dunal ridges
Cliff
Sandflat
River mouth - bars
Water bodies
Creek bar
Swamps
N
0 3 6
Km

as the presence of cobbles and pebbles at Dahanu and Navapur coast indicates their deposition during a regressive phase of the sea, when this coarse material was dumped by the rivers in the near shore areas. The longitudinal sandy ridge behind the backshore points to an ancient barrier ridge which had grown during the Flandrian transgression. The beachrocks appear to have been deposited when sea level was raised during the Flandrian transgression.

Landforms of the study area have been categorised as under :

i - Shoreline landforms : Beach, spit, Rocky platform, Sea-cliffs and coastal dunes

ii - Inland landforms : tidal flats, beachrocks, alluvial plains and residual soil

iii- Trappean landforms

SHORELINE LANDFORMS

The shoreline segment between Dahanu and Kora provides a variety of depositional and erosioanl landforms, characterised by estuarine river mouths, Beach, rocky platforms, sea-cliffs and coastal dunes. Stretches of shorelines of the study area lyeing between nine creek mouths, from north to south, show marked diversity in respect of morphological details and sediment characteristics.

Beach

A beach is very commonly a temporary deposit. It is alternately deposited and removed in what have been termed as "beach cycles". The most important of such cycles is the annual cycle marked by a very stormy season with strong and high waves. during the period of south west monsoon. Another beach cycle is a fortnightly cycle related to spring tides and neap tides. A third type of cycle is related to storms. In all these cycles, the periods of higher waves are those of the erosion of the beaches. The calmer periods of waves are those when the beach is extended seaward by deposition. The repetition of this process leds to the building of the Dahanu-Kora beach.

Beach materials vary from place to place, both physically and chemically, but the most important variations are particle size, roundness and percentage of major constituents. Particle size determine the form, shape and slope of the beach. Shingle and pebbles are usually forming very steep slope.

The steeper gradient with increasing grain size is due to the variation in percolation rate through the beach materials. Coarse sand and shingles are very permeable to water and when the swash strikes the beach, its energy is dissipated by percolation through the coarse beach materials and the backwash is consequently reduced. Owing to the low percolation in fine sand beach, the backwash is stronger than swash so that the former easily erodes the beach sediments. The beach varies in

width from 200 m to as much as 900 m and is dissected by Dahanu, Tarapur, Navapur, Mahim and Danda creeks. The thickness of the sand accumulation is variable, at places it could be several meters thick while at other it is only a few centimeters in thickness so much so that rocky platforms commonly peep out. The beach development is more or less restricted to pocket coasts between the various headlands. The beach gently slopes (<1°) seaward. On landward it is flanked by the various backshore dunes.

The beaches developed along Dahanu-Kora coast are of three types, namely the sandy beaches, the pebbly beaches and the rocky beaches. The sandy beaches occur between the headlands are crescent shaped and are commonly referred as pocket beaches. The sandy beaches are seen well developed along Dahanu, Vadhvan, Tarapur, Mahim and Usarni coast. The rocky beaches are mainly the shore platforms from which sand has been swept off by strong waves. They are made up of large boulders of basalt and are ideally seen at Vadhavan, Tarapur, Muramba, Danda and Kora coast. The debris has been provided by basalt outcrops from intertidal zone and also from inland areas. The gravel beaches of study are can be divided into movable and immovable ones depending on their relation to the present day hydrodynamic conditions. Best example of movable gravel beaches is found at Navapur, Muramba coast (Plate IV.1). This movable gravel beach corresponds to the recent hydrodynamics conditions and so they change continuously along with the grain size and morphology of beaches. They are

persistently shifted by the long shore current along the shore and move alternately land and seaward by other shore processes. Gravel beach near Dahanu creek represents good example of immovable beach (Plate IV.2). This immovable beach does not effect by present day hydrodynamical conditions and the grain size composition does not modified. Beach formation typically points to a regressive strandlines (Shepard, 1966; King, 1964, Zenkorich, 1967, and Kumar, 1976). The indented nature of the shoreline has inhibited beach development and beaches occupy the bay portions only separated by projecting headlands. King (1966) has called such beaches as bay head beaches. The beach material mainly comprises carbonate sands made up of broken shell fragments, quartz, chalcedony, agate and basaltic rock fragments. Different unbroken invertebrate fossils are commonly found in backshore zone. At places, concentrations of black sands are also recorded.

The beach sands of the sutdy area been derived from the following sources.

1. Most of the sediments on coast was transported by various rivers from the inland areas,
2. The sediments were brought to the Gulf waters by the various rivers of the mainland Gujarat and reworked by longshore current,
3. The intertidal rocky platform, also contributed the sediments, and
4. The various organisms provide biogentic material to the beach.

PLATE : IV.1 Movable gravel beach at Navapur coastline.

PLATE : IV.2 Immovable gravel beach at Dahanu coastline.

Waves bring sediments on shore from deeper part, but most of this sediments were previously carried to the sea by rivers. Beach sediments is continously subjected to transport by swash action. Under this influence, the sediments are moved to the maximum upslope limit of the uprash. The incoming waves are seldom parallel to the coast, with the result that the material is transported at an angle to the beachface slope. After the energy of the uprush has been spent, the backwash and the contained sediments run down slope in the direction of the steepest beach gradient. The grains, therefore, move in a series of parabolic paths up and down the slope. The main features of Dhanu-Kora beach are Backshore zone, Upper foreshore, Middle foreshore and Lower foreshore zones.

BackShore

It extends seaward from the cliff foot to the high tide wave swash. The berm crest separates the backshore from the foreshore by a sharp slope discontinuity. In this zone of a beach, one or more beach ridges are seen aligned almost parallel to the coast. The backshore of the study area extends for about (5-20 m) and is made up of pebbles, coarse sands and shell fragments.

Upper Foreshore

The upper foreshore stretches for about (10-70 m) width and the sands are shelly, with a considerable percentage of quartz grains. Some pebbles and shingles are found over the surface.

Middle Foreshore

The middle foreshore is comparatively broader, with a width of about (150-500 m) and has a slope of less than 2 degree. The sands are medium to fine. Various sedimentary structures such as, beach cups, swash marks, V-shaped structures, rill marks, mudd balls, rhomboidal structures ripple marks, besides tracks and trails and burrows of organisms are observed.

Lower Foreshore

The lower foreshore region of the area is rather muddy and is supporting the growth of mangrove plants. The width of lower foreshore is about (100-400m) with a gentle slope and abuntant outcropping of the trap rocks. It is usually consist of of fine shells and mud.

Spit

Some of the best developed spits of the world are found on the shores of inland lakes, land-locked sea, and coastal lagoons (Bird, 1969). In the study area good spits are found near the mouth of Dhanu creek and Dudh river. Here the spit appears to grow in the direction of the longshore drift as a submerged feature. Rao and Vaidyanadhan (1979) have described spits respectively from the prograding delta front of the Krishna and Godavari rivers in the Bay of Bengal. According to ehm spit of Krishna & Godavari rivers are of cuspate type face to strong

effect of wave refraction. In contrast to this the spits of Dahanu-Kora coast are still in the stage of their formation.

Rocky Platforms

Outcropping of Deccan Trap on the intertidal zone marks an erosional features (Plate IV.3). The constant abrasion of these rocks by marine process has given rise to wave cut platforms. At places these rocky headlands extend into the sea, pimparting an irregular shape to the shoreline. Occasionally, a thin layer of mud derived from the weathered trap rock supports mangrove plants. These are seen on south Tarapur coast.

The author has also observed remnants of an abandoned wave cut platform at Dahanu, Muramba and Mahim. This abandoned platforms are obviously related to the last higher standline. It is seen occuring at slightly above present day sea level.

Sea-Cliffs

Cliffs and shore platforms are often associated together on coasts where erosional processes are important. Cliffs are formed by a combination of marine under cutting and subaerial processes. The alluvial cliffs are more pronounced at Dahanu, Vadhawan, Nawapur, Muramba and N.Danda creek. Nearer to the Nawapur and Danda creek, it is observed that the raised alluvium forms distinct cliffs, about 5 meters above the high water line (Plate IV.4). These cliffs are on account of the constant action of the marine erosion of the sea. Most of the cliffs present in

PLATE : IV.3 Intertidal rocky platforms showing erosional features.

PLATE : IV.4 The alluvial cliff at Navapur coastline.

the study area are of vertical type. The heights of the cliffs vary from 2 m to 6 m. The processes responsible for the development of these cliffs are (i) over steepening of the cliffs by wave action, (ii) Height of sea level - high spring tides, storm surges and frequent tidal inundation of the cliff base are most conductive to rapid cliff retreat and (iii) orientation of the coast, by its control over wave energy.

Navapur and Mangelvad shoreline are having cliffs of two generations such as dead cliffs and the present day cliffs. Dead cliffs are few metres higher than the present day cliffs. These dead cliffs appear to be related to the strandline which was higher by 5 to 8 m during the Flandrian transgression. At Danda creek and Usarni coast beach rocks are on seen forming a vertical cliff near high water line and covered by alluviam (Plate IV.5).

Dunes

Coastal sand dunes are characterised by several distinct features. The dunes themselves often show a regular succession from the more active and unstable foredunes at the top of the beach to the older, more stable vegetated dunes inland.

On Dahanu coast there are several generations of sand dunes present in the form of ridge after the ridge which indicates subsequent formation of dune system (Plate IV.6). At Navapur

PLATE : IV.5 Beachrocks showing a vertical cliff near high waterline at Danda.

PLATE : IV.6 Different generations of sand dunes at Navapur coast.

coast the dune grows to its maximum height and then erodes moving landwards. The Nawapur sand dunes show decrease in height of ridge landward. The coastal dunes of the area have been classified in to two type as under :

(i) Stabilized dunes (Semi-consolidated)

(ii) Migrating dunes (Un consolidated)

The main difference between the two is that the former supports vegetation (Plate IV.7), whereas the migrating dunes are devoid of the same (Plate IV.8). Both consist of unconsolidated sediments generally of silt size. A good example of stabilized dune is seen at Mangelvad and Usarani coast. The stabilization is on account of vegetational growth on their surface. The vertical growth of these dunes coincident with very little horizontal migration, results in a distinctive internal dune geometry (Yaalon, 1975). Unconsolidated dunes are in the process of formation at present and are encountered almost all along the backshore. These migrating dunes or transverse dune ridges are characterized by a lack of anchoring vegetation, more generally landward in response to the prevailing winds and it stands as single large distinct features. Because of their over lapping nature such dunes have been called as `complex dunes´ by (Makee, 1966).

PLATE : IV.7 The stabilized dunes at Dahanu.

PLATE : IV.8 Migrating dunes of Usarni coast.

INLAND LANDFORMS

Tidal Flats

Tidal flats are defined as bodies of sediments aggraded by the sea into bays whose water surface is maintained by tidal currents approximately at the mid-level between the high and low tide (Reineck, 1955). The following factors are taken as distinctive for the recognition of tidal flats :

1. Periodical desiccation of large areas of sediments during the low tide,
2. Reworked of eolian and fluvial sediments by marine processes and
3. High percentage of marine sediments in the tidal flats.

These near horizontal mud deposits, characterising the present day intertidal zone, are encountered all along the coast line of the study area either near the river mouths or at the inland creeks and lagoons. These essentially comprise a land feature that ideally reflects a receeding sea level. During the early Holocene the sea had risen several metres and had given rise to numerous estuaries and linear lagoons behind the coastal dunes. Constantly under the influence of high tides, these estuarine, lagoonal and creek areas, provide featureless mud accumulations controlled by a mixed environment. The infilling of the tidal flat areas by eolian, fluvial and marine sediments had given rise to these deposits. River borne sediments are partially trapped in the estuaries by the predominantly landward

flow of estuarine bottom waters. Tidal currents transport large volumes of silt and clay-sized fractions which settle on the floor of bays and estuaries. The deposits gradually accumulate over a long period ultimately forming mudflats. The extent of the tidal flats depends upon the amount of infilling, slope of the area and tidal range.

At Dahanu, there occurs a NNW-SSE trending 5 km. long tidal creek that tapers gradually landward. Into this creek flow numerous local streams. Trappean hills rise rather abruptly beyond this creek to the east. From Dahanu to Agashi Bay, the coast line of the area is marked by numerous creeks (Tarapur, Navapur, Mahim and Danda) of sizable dimensions (2 to 8 km long).

The sediments of the above tidal flats are dark brown, fine grained and contain organic matters. The intertidal mudflat at Dahanu is usually fine grained, with predominant silt and clay fractions. Vegetation is very sparse in these tidal flats.

Parallel laminations consisting of alternate coarse and fine material formed due to the seasonal fluctuations in suspended sediments are seen occasionally along the sides of the tidal inlets.

In vertical section, clay, silt, and fine sand are seen as alternating layers. The sandy layers are deposited during high currents whereas the muddy layers formed during low energy. The

influx of sediments into the tidal flats is a result of several phenomena. In a marsh, tidal current velocities tend to decrease landward and therefore the net grain size of sediments carried in suspension also decrease accordingly and more suspended sediment reach the bottom at high tide than at low tide, resulting in the deposition within the tidal flat (Curray, 1969). Various types of ripples are common, in this tidal mud having varying wave length and amplitude. Biogenic sedimentary structures are seen on these tidal flats. Mud cracks occur very commonly on these flats (Plate IV.9). These cracks are either straight or gently curved in plane view and are bounded by more than three sides. Their shapes vary but are usually elongated, oblong or rectangular. The length of the polygon of the cracks vary from 5-35 cm, while the depths are as much as 12 cm.

Supratidal flats occurs above mean high tide level and therefore it is sensitive to climate. Their shape and size depend upon those of the depressed areas that they occupy. These represent ancient intertidal zone when the sea-level was higher than the present and obviously formed during the Flandrian transgression. The raised mudflats supporting a thick vegetation are found at Dahanu, Mahim and Muramba coast. Within the high marsh areas, a few dotted exposures of the remnants of the alluvium occur at slightly higher elevations. These patehes of relict alluvium are more common in the area south of Dahanu. These patches of alluvium cropping above the marshes comprise remants of older fluviatile material deposited at the time when

sea was below the present level. Depostion of tidal flats appear to occur in the following four closely related environments (i) saltmarshes, (2) high tidalflats, (3) lowtidal flats and (4) tidal channels.

1. Salt Marshes

Salt marshes are characterized by abundant grass and shells of marine invertebrates. The marsh creeks of Dahanu, Tarapur, Muramba, Mahim and Danda are of a well-developed meandering habit, some are bordered by low natural levees, and in some areas like Mahim and Danda, show a striking flow pattern which consists of a network of smaller creeks that flow landward and a few major creeks which flow directly seaward.

2. Hightidal Flats

Where salt marsh creeks empty on to hightidal flats, the meandering creek changes in to a series of small braided, shallow channels. The higher flats contain abundant grass, marine invertebrates mostly (Pelecypods, gasterpods and warms).

3. Lowertidal Flats

The lower flats consist of grassless mud, into which meandering water coarses have been incised.

4. Tidal Channels

The high water line is highly crenulated and shows numerous tidal creeks and channels, imparting considerable irregularity to the shoreline configuration. These creeks typically represent drowned river coarses and point to submergence of river valleys during the last (Flandrian) transgression. Prior to which the rivers extended several kilometres in the offshore direction when the sea level was much below the present. The branching channels towards the tidal flats is a characteristic morphological feature of tidal flats. These channels resemble rivers by their meandering coarse and system of tributaries. Channels width ranges from several centimetres to several metres and commonly have highly sincous channel patterns with point bar on the inner depositional bank. It possess semicircular tongue or trumpet shaped bodies. Mouth bar is essentially a constructional landforms that develop at the mouth of a river. The debris brought to the river is redistributed by the coastal processes, and generally with its progressive growth its shape goes on

changing and also it finally makes a striking feature rising above the high water line with a fluctuating sea level. Good example of mouth bar are seen at Dahanu and Muramba coast. Point bars very considerably depending partly on the degree of sinuosity of the meander (Bridges & Leeder, 1976; Barwis, 1978). Sand shoals or bars exist at the mouth of the channels and between the channels creating a sand dominated depositional provinance. The tidal channels carry the bulk of the water in and out of the sea channel floor are always submerged, even at low tide.

Nearer to the low water line (Plate IV.10) mangrove swamps are found at Muramba and Tarapur coast. The mangrove growth depends mainly on low salinity and low energy being conductive to their growth. At Tarapur and Muramba coast, rocky platform and Dudh river, forming a protected area, provides a low wave energy environment. The river water tends to reduce the salinity. As a result, the mangrove swamps have developed at Muramba coast.

Beach Rocks

The occurrence of beach rocks are seen at (Dahanu, Vadhavan, Chinchani, Navapur, Alevadi, Muramba, Mahim, Panavi, Danda and Usarani. They occur as small patches and isolated thin beds dipping sea ward (5°-10°) and ranges in thickness from 0 to 4 m, are seen occur few metres above the present high water line. The beach rocks occur in the intertidal zone as well as in land ward as far as 200 m to 700 m from coastline. They are deposited about 2 to 8 m high above mean sea level.

Alluvial Plains and Residual Soil

The alluvial plain and residual soil extends right from the coastal ridge eastward to the foot of the trappean hills its thickness increases northward and decreases southward. Alluvium has been deposited by the various rivers since the time the Tyrrtienian sea regressed. The thickness of alluvium 1 to 2 m in

PLATE : IV.9 The development of Mud cracks in the backzone of Dahanu.

PLATE : IV.10 Mangroove swamps near the low waterline at Murambe.

most of study area. Alluvium consists mainly of siltsized particles with some amount of sand & clay. Residual soil are the weathered products of basaltic rocks that have not undergone transportation.

TRAPPEAN LANDFORMS

To the east of the alluvial plain, the trappean hill ranges rise abruptly giving rise to a rocky terrain with averaging heights from 109 m to 471 m. Erosion of the trap hills has given rise to linear ridges, mesas, conical hills and detached hillocks. The plateau basalt has also been curved out into numerous flat topped hillocks. Some of the linear ridges, run parallel to the coastline for about 10 km.

The flat topped hills are observed at north of Kaldurg (358 m), Kaldurg (471 m), south of Kaldurg (383 m), near the village lathane (471 m) Karavla (175 m), Chikkhalpada (219 m), Raitale (247 m), Vakvalipada (275 m), and near Vakorapadga (327 m). This flat topped hills are formed due to the operation of pedipplanation cycle during which the hill slope prgressively retreated parallel to these hills. The mesas represented and intermediate stage in this retreat and the conical hills, a near end stage. The hill tops are circular, oval or elongated in shape.

The trappean landforms are horizontal over a major part of the rea but have acquired ahomoclinal dip at several folded. One account of differential weathering the westerly slope of the trap is very clear. This is very well seen at lathane (471 m). Differential weathering has also developed annular depression around central rises on the top surface of polygonal colums weathering of the trap tocks has also given rise to black cotton soil whose thickness varies from few centimetres to couple of metres.

The isolated hills are subjected to the processes of weathering and down wasting to give rise to peneplain.

At the foot of the hills, rock debris consisting of a heterogeneous mixture of boulders, small fragments and powdery fines is invariably seen.

Multiple ridges have been reocrded at Ashagarh, Kotbi, Vatvalipada and Devkhop. In the past detached hills were the parts of continuous plateau whose erosion had carved these small hillocks in to isolated patches, prior to the deposition of the alluvium. At pale one such feature is seen number of such features are also common in the coastal plain of study area. Most of these hills have undergone pronounced erosion and denudation with the result that few show steep carps and now mainly appear as elongated ridges. They are now seen covered by

thick forest. Multiple scarps are observed at lathane peak (471 m) in the southern part of the study area.

LANDFORMS EVOLUTION

The existing geomorphic set up of the coastal segment under study, typically provides an evolutionary sequence, wherein global geodynamic processes, neotectonism, ecstasy and subaerial proceses of erosion and deposiion have all contributed their share at apporiate stages of the landform evolution. A critical assessment of the vrious landforms encountered, points to a sequence of events, initiated with the breaking up of the Gondwanaland at the close of the mesozoic, and culminated in to the present day coastline processes of erosion and deposition. Considerint all aspects, including data from the neighbouring areas, the author has worked out the following evolutionary sequence for the study area.

1. Breaking up of the Gondwanaland during the cretaceous period.
2. Formation of west coast fault.
3. Emplacement of west Deccan Lava flows, followed by dyke rocks.
4. Extensive fracturing and jointing of the trap on account of the N-E movement of the Indian plate.

These events played very important role in formation following I and II order landforms as continental shelf, older

coastal dunes, recent coastal dunes, beaches, mangrove (swamps) and Tidal flats etc..

The study are undertaken exhibites a variety of landforms suggestive of both submergence and emergence of the coast. Various estuaries found at Dahanu-Kora coast along with drowned river valleys, headlands associated with cliffs and well developed beaches are the evidence of submergence while evidences of emergence occur in the form of beachrocks. The above characteristics suggest that the coast under study, may be included in the category of Johnson (1919) classification of coast i.e. compound coast showing both emergence & submergence. The coast of the study area shows dominance of submergene over emergence on account of the rise of the sea level that followed the last regressive period. The occurrence of beach rocks along Dahanu Kora coast looks like a contradiction to it but it only means that what we now see is the algebraic sum of a long history of ups and downs. The last major eustatic rise of sea level has ensured that a majority of shore lines of study are still retain the characteristics of submergence. On account of eustatic rise of sea level during the early part of the late pleistocene the trappean landforms were inundated several kilometres inland (Tyrrhenian - 40-45 m above present day M.S.L.).

The limit of this higher seastand is indicated by the boundary that marks the abrupt rise of hilly terrains above the thin soil covered plains. It appears that it was during this period that erosional activities of the sea brough about the

planation of the rocky terrain. The subsequent regression of the sea, which could be related to the last glacial stage (Wiirm), the strandline retreated and finally stood at about -20 m. It was during this regression that the various rivers extended their courses several kilometres westward, dumped their pebbly and copply load in areas now under shallow water and also gave rise a thick alluvial deposits.

At the close of Pleistocene the sea level rose again (+5 - +8 m) characterising the Flandrian transgression. It was in thsi high sea that the existing of raised mudflats, beach rocks and palaeobars were formed. The areas landward of these were flooded and large lagoons were formed. The alluvial deposits at the coastline were washed away and only few relict patches were left untouched. The present day sea level is responsible for the various shoreline features.

From the structural framework of the western part of the Deccan volcanic, it is evident that the coastline of the study area is also structurally controlled and developed along or parallel to the west coast fault. The development of Dahanu, Chinchani, Navapur, Muramba, Mahim and Danda creeks has also taken place along prominent lineament. West coast processes played and important role in development of various beaches along Dahanu-Kora coast. They have caused the erosion leading to the development of erosional landforms (wave cut platforms and

cliffs) and they were also responsible for the transportation and deposition of sediments giving rise to well developed beaches, spits, dunes, beachrocks and tidal flats.